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ABSTRACT

This paper analyzes the relative contributions of general reading comprehension and domain knowledge to subject matter text learning. The paper points out the limits of each factor in explaining text learning and summarizes some recent studies that support the complementary role played by each factor. A two-factor account of text learning (general ability and specific knowledge) is shown to be better but still inadequate without careful attention to the role of text structure, which includes both domain and strictly linguistic components. The paper concludes that these text components play pivotal but complex roles in text learning. (Twelve footnotes are included; 36 references are attached.) (Author/RS)

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Subject Matter Text Learning: Reading, Knowledge, and Texts

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ABSTRACT

This papers analyzes the relative contributions of general reading comprehension and domain knowledge to subject matter text learning. It points out the limits of each factor in explaining text learning, and summarizes some recent studies that support the complementary role played by each factor. A two-factor account of text learning (general ability and specific knowledge) is shown to be better, but still inadequate without careful attention to the role of text structure, which includes both domain components and strictly linguistic components. These text components play pivotal but complex roles in text learning.

Subject Matter Text Learning:

Reading, Knowledge, and Texts

Learning from subject matter text books comprises a major portion of a student's educational experience. How does such learning occur?

Consider two general classes of accounts that might answer this question: The first emphasizes the abilities of the student in general skills of understanding. Learning from a text proceeds by reading words, comprehending sentences, and integrating each sentence with those sentences already read. Learning from a text is a matter of generalized reading skills. Students will learn from a text in proportion to their general abilities at text comprehension. We will call this the generalized comprehension account of text learning. Students acquire basic skills at comprehending printed language and apply this skill to specific texts.

The second account emphasizes the specific knowledge the student has concerning the subject matter of the text that he or she is trying to learn from. If the student is reading a text about the structure of the atom, for example, the critical factor for learning is the extent to which the student has relevant knowledge about atomic structures. If the student is reading a history text

about the American Civil War, the critical ingredient is the extent to which he or she has relevant knowledge about Civil-War related topics. Let's call this the specific knowledge account of text learning.

Of course, neither of these two accounts could be correct without some accomodation of the alternative account. (Indeed these accounts are too extremely stated to be actually embraced by anyone, as far as we know.) It is, in other words, natural to assume that elements of both accounts are required. Before following this path of compromise, however, it is useful to explore a bit more what each of these accounts entails. By noticing what follows from a particularly strong version of each account, we might see more clearly just what is lacking and just what kinds of accommodations each has to make.

The Generalized Comprehension Story

The generalized comprehension account assumes that reading comprehension is the central part of learning, and more strongly, that general comprehension skills serve all domains in more or less the same fashion. The exact inventory of comprehension skills might be open to some debate, but by any account it would include the whole range of generalized language abilities plus abilities that might be specific to written texts. A minimal list would refer to basic syntactic and morphological abilities, sentence integration

abilities, and effective (mainly automatic) word identification abilities. An expanded list would include inferential abilities, comprehension monitoring abilities, and other skills that have putative general components. That various talents for written language comprehension might be linked to one or two basic processing mechanisms, e.g. efficient working memories and automatic word identification, remains a possibility (Daneman & Carpenter, 1980; Perfetti, 1985; Crain & Shankweiler, 1988.) Another possibility is that some seemingly general inferential processes are domain specific. It is difficult to be sure that some process that one imagines to be general to language comprehension does not have some specific knowledge component. For purposes of tracking the implications of the generalized comprehension story, however, it is important to assume that there are some general abilities.

So as to not beg the question of whether there is any distinction between the general language abilities and specific domain knowledge, it is useful to assume that the former are a fairly restricted set of abilities. It is possible the distinction between the general and the specific cannot be maintained in any event, but the distinction will surely collapse if we have such powerful general abilities that they subsume what would otherwise be specific knowledge. General comprehension abilities include just

those language processes that serve the reader in understanding the text to a fairly superficial level (Perfetti, 1989). Abilities that lead to deeper understanding of text must include very specific knowledge.

The generalized comprehension account, taken at face value, implies that students will learn equally well from all kinds of texts. Before such an implication can be dismissed entirely, it is necessary to grant its critical ceteris paribus: The texts themselves must be equivalent as texts, i.e. in terms of whatever linguistic characteristics contribute to "text difficulty" and, more generally, to any intrinsic text property that might affect learning. Of course, there is no reason to expect any two texts to be free of such differences. A text about the Civil War is not likely to be the at the same level of text difficulty as a text about the atom. Here, however, we beg another question: What is text difficulty?

Text Difficulty: A General Linguistic Account

Is the impression that a science text might be more difficult as text one based on its less familiar content? If it's the fact that the science text is about electrons, protons and such that makes it difficult, that's not what one usually means by "text difficulty". Text difficulty, if it's to be distinguished from domain knowledge, must refer to text-linguistic factors. Whatever

these factors ought to be, they must be something other than the vocabulary that is specific to a particular knowledge domain.

There are of course, many useful ideas about how to measure the "readability" of texts, an interesting collection of which is contained in Davison and Green (1988). On the other hand, there has a been general condemnation of "readability formulae" on a number of grounds. Historically, readability formulae have been rather less guided by psychological and linguistic research than by intuitively reasonable and pragmatically useful measures of word length, vocabulary, and sentence length. (See Anderson and Davison, (1988) for an interesting review.) Nevertheless, some attempts have been made to at least demonstrate that there are psychologically and linguistically principled possibilities in measuring text difficulty. Kintsch and Vipond (1979) developed the idea that the reader's working memory capacity can be taken into account in conjunction with the properties of information in the text, in particular the extent to which the text structure requires information to be integrated across sentences and clauses. Some recent research in linguistics might further be used as basis for distinguishing sources of linguistic difficulty according to the surface structure demands of sentence and the requirements of linguistic integration (Smith, 1988).

The point to be made in the present context is that we should

take seriously the possibility that genuine and totally general text processing factors can be assessed. These assessments will not take into account vocabulary differences, which must be considered part of the subject matter domain problem, not part of the "readability" problem.[1] They will take into account such things as the surface syntax of a sentence, the distance between elements that must be "bound" together linguistically, and possibly other factors that are purely linguistic. Because they are purely linguistic they are fully general. They will apply to a history text as well as to a science text.

To make this concrete, consider two hypothetical examples, one from a science text and the second from a history text.

(1) An atom with more electrons than protons will not be stable. It will lose its extra electron.

Disregarding the meaning of the words "electron" , "proton" and "atom" (these are aspects of domain knowledge), one difficulty a reader will have with the first sentence is in understanding with more electrons than protons. This phrase must be syntactically attached to the noun phrase the atom, which is simple enough on the surface. Making this attachment, however, has some cost. Instead of having a simple noun phrase--the atom--to which the verb phrase (will not be stable) can be attached, the reader has to build a complex extended noun phrase -- the atom with more electrons than

protons. It is this entire extended noun phrase to which the will not be stable gets attached. There are several specific problems this can cause. The reader can fail to build the extended phrase because of limited processing capacity. A common misreading of this sentence for a reader of low skill is to attach proton to will be unstable. This arises because as proton is encountered, its syntactic relation to electron has been lost through the reader's capacity being exceeded by the processing demands of the text. This, in effect, leaves the reader with the wrong meaning after reading the first sentence and makes it likely that a second crucial error will be made on the second sentence: When the reader encounters it, he must "bind" it to its antecedent. The antecedent must be the entire extended noun phrase, the atom with more electrons than protons. But the reader here has only the last noun from that phrase, so he "binds" it to proton. for this reader, protons lose electrons.

There are other errors of this type that could be traced through this example. The main point is that the syntax of the sentence, in combination with limited processing capacity, provides an opportunity for error. And the errors get compounded, because the next segment of text builds on representations established in the previous segment. Such an error is not likely to be correctly diagnosed. We are likely to conclude merely that the student

doesn't have a clear idea of what a proton is. He confuses protons with atoms.

Consider now the second example, from a history text.

(2) The negotiations with the Columbian representatives collapsed. They would not be revived.

Notice this pair of sentences is roughly parallel to the pair in example (1). The reader must again build an extended noun phrase--The negotiations with the Columbian representatives--and there is again the opportunity for a processing breakdown. The reader might lose track of the noun phrase begun with the first word, and try to attach collapsed to representatives. The they of the next sentence, which must be bound to something, could be bound mistakenly to representatives. There are some other differences between the two examples that we will ignore for the present purpose.[2] The main point is that we have essentially the same potential problem in texts from two different domains. When we consider text factors, these are the kinds of things we must take into account. It's not the electrons, protons, and neutrons versus the negotiations, Columbia, and the representatives that matter for text difficulty. The former get their meaning from the discourse of atomic structure and the latter from the discourse of diplomatic history. They are domain differences. What matters for general factors of text difficulty is the linguistic structures, both the

syntax of individual sentences and the integration of meanings across sentences.

The Role of Knowledge in the Generalized Comprehension Account

It is hard to avoid the impression that the syntactic factors we described are less likely to be a problem for the reader of the history text (2) than for the reader of the science text (1). We are not sure everyone will share this intuition, but it is worth assuming it is correct to explore what we see as the critical connection between domain knowledge and text difficulty: Domain knowledge allows the reader to repair processing mistakes.

What this means can best be seen by looking again at example (2). Despite the possible processing difficulty described above, it seems rather unlikely that readers will attach collapsed to representatives rather than to negotiations. Or rather it is very unlikely that they will fail to correct an attachment error.[3] The correction for (2) is not difficult. While the reader might consider a momentary attachment of collapsed to representatives, he can use what he already knows about the topic being discussed to correct that misanalysis. Notice that it is not that the representatives might not have collapsed, because they might have. It's rather that the either the prior text or the reader's knowledge or both might cause a quick rejection of that possibility. Even with relatively little knowledge about diplomatic

discourse, e.g., not knowing exactly what happens when negotiations "collapse", the reader can decide that whatever is going on is about the negotiations rather than the representatives.

In the atom case, this outcome seems a bit less secure. If the reader now has firmly established that atoms have protons and electrons, and that protons do not "have" electrons, a repair is certainly possible. The problem will occur if this knowledge has not been firmly established. This is, indeed, the common case for the texts of this kind. The text has just informed the reader about atoms having protons and electrons. But he may not have a good understanding of this. The reader may not have developed a nonlinguistic mental representation of the atom, but only a superficial linguistic representation. The absence of a semantically useful mental model (Johnson-Laird 1983) of the atom implies that words such as electron, proton, neutron, and even atom itself will bounce around like so much lexical debris after a conceptual explosion.

To summarize, the Generalized Comprehension account must take some notice of how the knowledge that the reader has combines with general comprehension skills. The minimum bow to specific knowledge is to suggest that it has a role in minimizing the damage done by ineffective general language processes. The confrontation between texts as linguistic objects and the reader's processing abilities

reveals the general processes in reading. The confrontation of texts as knowledge objects and the reader's individual knowledge reveals the knowledge component in reading.

The Specific Knowledge Story

The Specific Knowledge account assumes that learning from tests is driven by knowledge of what the text is about. Of course, it must accommodate some generalized reading comprehension ability. A minimalist assumption here is that the reader must be able to read words and have whatever minimal knowledge of language is necessary. The remainder of learning from text rests on what the reader knows about the specific subject matter.

The empirical basis for a specific knowledge account lies in the many demonstrations of the importance of knowledge for comprehension (Anderson, Reynolds, Schallert, & Goetz, 1977; Bransford & Johnson, 1972; Spilich, Vesonder, Chiesi, & Voss, 1979).

If the main dubious implication of the Generalized Comprehension account is that readers will learn equally from all sorts of texts, the main dubious implication of the Specific Knowledge Hypothesis appears to be what Bereiter (1985) termed the learner's paradox. If prior learning is necessary for learning, how can learning get started for the untutored? It is certainly the case that the Specific Knowledge account has a "rich get richer"

quality to it. Surely, however, students without significant specific knowledge can learn from text.

There is a gray area of retreat, just as there was for the Generalized Comprehension account. This is the question of what counts as relevant knowledge. Consider two students measured to be identical in relevant specific knowledge, for some particular domain, but unequal in general comprehension ability. The chances are that the comprehension measure on which they differ included quite a bit of paragraph comprehension that required specific knowledge in the form of vocabulary, paragraph topic, or other information not uniformly available to all readers. If these students are found to differ in comprehension on the specific text for which their knowledge is assumed to be equal, the inference will be that the difference is due to generalized comprehension skill. But if the comprehension measure itself already has a large but disguised component of specific knowledge in it, this inference is unwarranted. It may be that the "comprehension" measure has tapped more of the relevant knowledge than the specific knowledge measure. For example, if the subject matter is science, is a student's score on some standardized science test the best measure of his or her relevant domain knowledge? Wouldn't the most appropriate measure be one that examines the student's knowledge for concepts that are directly needed to understand the specific

text in question? In other words, is the student's knowledge about science "in general" really what's important for his learning about atoms?[4]

What we have is a three cornered measurement problem. Measures of text difficulty usually fail to separate domain knowledge, especially vocabulary, from text-linguistic factors. Measures of reading comprehension typically fail to separate specific knowledge, especially vocabulary, from generalized comprehension ability. And measures of domain specific knowledge may only approximate the kind of knowledge that is required in a given subject matter text.

To summarize: Both the Generalized Comprehension Story and the Specific Knowledge Story have some implications that seem wrong. The Generalized Comprehension Story seems to imply that all topics are equally learnable and the Specific Knowledge Story seems to imply that only learners who already know can learn what it is they already know. Of course these implications are parodies. No one who emphasizes general comprehension abilities assumes that knowledge is unimportant. And no one who emphasizes specific knowledge assumes that general comprehension is unimportant. It is, after all, just a question of emphasis.

The Easy Compromise: Text Learning = GCA x SK

Let us assume that both generalized comprehension ability

(GCA) and specific knowledge (SK) play a role in learning from text. What does that get us other than the virtuous feeling that accompanies common sense? The answer remains to be seen, but we can again forge ahead to consider the implications of this compromise.

First, it seems likely that the function relating GCA and SK must be multiplicative rather than additive. Or at the least, total learning requires some minimum contribution from both components. When GCA=0, then total learning must be 0 also. And when SK=0, then total learning must again be 0. Still one mustn't take such suggestions too seriously, because the ability to measure the two components is not so good, at least in actual practice. Besides, an equation is just an equation, whether it is additive or partly multiplicative. It is more useful to explore how the components might actually contribute to learning, a question we will return to later in the final section of the paper. First we will review some research that demonstrates what we think must be taken into account in a comprehensive account of text learning, one that attends to both general comprehension ability and specific knowledge.

A Trading Relation between Knowledge & Comprehension

Adams, Bell & Perfetti (in press) identified groups of students in the fourth through seventh grades in terms of the variability of their knowledge of American football. The idea was

to provide subjects with a narrative, a story about a hypothetical football game, and observe the relative contribution made to their reading comprehension from two sources: Their knowledge of football, as measured by a pre-test of football rules, and their general reading comprehension ability, as measured by a standardized reading comprehension test. Students read two stories, constructed so as to be parallel in overall narrative structure and story characters, and nearly equal in length and text readability (Coleman-Liau readability scores of 5.6. for the control story and 5.2. for the football story).[5]

The parallelism of the two stories is worth noting, in light of the previous discussion about text difficulty. Except for the use of a standard readability formula, there was no attempt to control for sentence syntax and inter-sentence connections, which are just the factors that ought to count for general domain-free measures of text difficulty. There was, however, attention to the text genre. Both texts were narratives and both followed the same narrative schema. Each had a hero, who was placed unexpectedly in a heroic situation. In the football text, it was a third string rookie quarterback who lead his team to dramatic victory following injuries to the first and second rank quarterbacks. In the control story, about a fire in a school, the hero was a janitor, who had to rescue a child after two others, a principal and a teacher,

failed. An initial paragraph of each story established a critical situation followed first by a flashback episode, important to the central character but peripheral to the action of the story, and then by the story action, a series of obstacles and the solutions used by the hero to overcome them. Matching the parallel story structures were parallel comprehension questions that were linked to parallel episodes in the respective story structures. In addition to the comprehension questions, story summaries and measures of subjects' reading times for the stories were taken.

There were several interesting results, based on regression analyses that predict reading comprehension and reading speed of the football story from measures of general comprehension and specific knowledge.[6] First consider comprehension. It turned out that the highest correlation of a comprehension measure with comprehension of the football story came from comprehension of the control story, not the general standardized comprehension test. This result is interesting in connection with the earlier discussion of the difficulty of measuring either knowledge or general comprehension as relatively "pure" abilities. The control text and the football text differed only in knowledge. One gets, in a sense, a better estimate of text-related comprehension factors in this way. To the extent that perfectly general abilities contribute to comprehension, then comprehension of the control

story should predict comprehension of the knowledge-dependent football story. (This correlation was r=.44.) A standardized comprehension measure, however, has a mix of text factors that will not be the same as any particular experimental passage. (It will of course have different kinds of knowledge factors as well.) Thus, while the correlation between the standardized measure and the football story was significant, it was not as high as the correlation between the football story and the control story. This, we suggest, carries a general lesson about individual difference text research: Measure skills in general text comprehension in a way that controls for whatever generalized text comprehension factors are reflected in experimental texts.

A second interesting result from Adams et al (in press) is the dual contribution to comprehension of the football text provided by general comprehension and specific knowledge. The best predictor was specific knowledge, r=.59. But general comprehension, as measured by the control story, added significantly to football comprehension, multiple r=.75. The agreeable conclusion is that for this particular range of individual differences in knowledge and general comprehension, there is a large contribution of both specific knowledge and general comprehension to the comprehension of a knowledge dependent text. The fact that one of these sources of comprehension can be partly traded off against the other is best

seen by noting that subjects who were high in comprehension but low in knowledge performed nearly identically on the football text to subjects who were low in comprehension but high in knowledge. We can refer to a trading relationship between general comprehension and specific knowledge.

A third result of interest from this study concerns the prediction of reading times on the football text. Unlike comprehension, the best prediction of reading times for the knowledge dependent text was reading time on the control story. The simple correlation was r=.87. Football knowledge did not account for significant additional variance in reading times. We thus have an interesting difference between speed of reading and comprehension. Speed of reading a knowledge demanding text is predicted primarily by speed of reading a comparable text and not by knowledge. We suggest that reading speed is especially sensitive to generalized reading factors in a way that comprehension is not. Individual differences in word identification, parsing, and other rate-constant operations play the dominant role here (as do individual differences in reading styles, e.g., a student's standards for comprehension.) By contrast, comprehension and learning are sensitive to both knowledge and general comprehension.

The Adams et al study makes a general demonstration that specific knowledge and general comprehension ability both

contribute to comprehension of a knowledge-demanding narrative text. We turn now to the case of subject matter texts. It is this case that is most interesting for the general question of how comprehension and specific knowledge contribute to subject matter learning.

History and Science Text Learning

A study by Britt, Bell & Perfetti (1990) echoes the contrast between history and science that we made earlier. The question in this study was how middle grade students of varied comprehension ability and background knowledge would handle middle grade texts in history and science. For the science text, we adapted a section on the structure of the atom from a 6th grade science text book. For the history text, we adapted a section on the Panama Canal from a 5th grade American History text book. Because it bears on the main points to be made, and because the study is not yet published, we will include a bit of detail from this study, especially concerning the nature of the texts.

After modifications of the texts resulting from a pilot experiment, the two texts were comparable in most superficial characteristics. Coleman-Liau readability was 9.1 for the science text and 9.5 for the history text. The average word length for the two texts was identical (4.64 letters) and the number of sentences was nearly so (42 for the science and 44 for history.) Differences

existed in number of words and number of words per sentence, with the history text averaging 15.3 words per sentence and the science text averaging 12.3 words per sentence. The history text had slightly less frequent words, 362 for history and 576 (per million) for science. Thus what differences there were between the two texts appeared to favor the science text.

The science text described the structure of matter, organized around three themes--the structure of the atom (the Bohr model), how atoms are combined, and the role of scientific models in understanding physical phenomena. The history text explained the building of the Panama Canal organized around four themes--the background of U.S. interest in a canal, the concept of balance of power as a model of international motivation, the acquisition of canal zone rights, and the problems of disease for canal workers.

Text Analysis. The content of each text was analyzed as a conceptual network. The network represents two kinds of propositional units, termed "textrons" and the relations among these units, termed "connectors".[7] The textrons were the set of unique propositions of the text minus referential and causal relations. The history and science texts had a total of 166 and 148 unique propositions. For the science text, 65% of these propositions were textrons and 35% were connectors. For the history text, 75% were textrons and 25% were connectors. Textrons were

further divided into those that were central--main points and core concepts--and those that were noncentral--incidental and supporting information. For the history text, an example of a central proposition was Columbia ruled Panama and a related proposition was U.S. asked permission from Columbia to build canal. Noncentral information included the name of the president (President Roosevelt), the amount of money the U.S. offered Columbia for rent ($10 million), and the date of the first use of the canal by a ship (August 15, 1914). The number of central textrons was 48 (39%) for history and 50 (52%) for science.

The connectors, relations among the textrons, were divided into causal relations (RESULT, ENABLE, NECESSARY, MOTIVATE) and referential connectors (MANNER, LOCATION, INSTANCE, QUALIFIER). The causal connectors were those textrons that were related temporally or causally (in the sense of co-occurrence). For instance, a MOTIVATE relation exists between the proposition war and the proposition move ships quickly while a NECESSARY relation holds between Columbia rules Panama and Need permission to build. The first connector reflects the text's description that the war with Spain, because it was fought on two oceans, prompted concern for rapid ship movement between the oceans. And, in the second case, the connector reflects the text's description of Columbia's control of Panama and the consequent need for the U.S. to obtain Columbia's

permission to build a Panamanian Canal. Referential connectors are those relations among textrons that connect to a referent (by qualifying it, locating it, etc.) rather than causally connecting two properties. For example, a QUALIFY connector, such as the connection between atom and small, is one in which the second textron modifies, refines, characterizes or is equated with the first textron. In a LOCATION relation the second textron designates the location of the referent of the first textron, as in the relation between build canal and through Central America. The total number of connectors that were causal was 30 (or 71%) for history and 17 (or 33%) for science. The total number of referential connectors for history and science was 12 (or 29%) and 35 (or 67%) respectively.

Student Measures. In addition to testing 5th and 6th grade students, we tested 4th graders and college students, thus bracketing the grade level for which the texts were targeted. Students' relevant knowledge for history and science was tested by standardized tests for science and social studies and by knowledge pretests keyed to the specific content of each text. For the science pre-test, students were asked such questions as "Do you know what an atom is?" "Have you heard of a molecule before? Tell me what you know about a molecule." "What is water made of?" For the history pretest, there were parallel questions such as "Do you

know what a canal is?" Have you heard of the Panama Canal? Tell me what you know about the Panama Canal." The history pre-test also included a map test, in which subjects were shown a flat unmarked map of the world and were asked to identify a number of relevant areas, including North and South America and the Pacific Ocean.

Learning Measures. Subjects were interviewed after reading each text by questions derived from the conceptual network used to represent the text's content. Prior to the interview, they were asked to orally summarize the text they had read. The protocols from the summary and the post-test interview were compared with the structural representations of the texts to obtain a measure of the proportion correct of the information the subjects produced. The measure of total learning refers to the combination of information obtained from the interview questions plus the recall.

There were two results of some interest from the Britt et al study. First, there was evidence of a generalized factor in learning from the two texts. Second there were differences in performance on the two texts that reflect differences in the structure of the texts themselves.

Evidence for Generalized Ability. The evidence for a generalized ability comes for the correlation between total learning for the two texts, which was very high for all subjects, r=.91, and moderately high for middle grade subjects only, r=.69.

In general, the subjects learning the most from one text are the same subjects learning the most from the other text. The high correlation does not seem to be an artifact of prior knowledge, especially for children. For children, pre-knowledge for history and science was actually slightly negatively correlated, r=-.24; while for adults the two were positively correlated, r=.62. At least for the children, it is not the case that the high correlations for the post-test are accountable by the pretest level of knowledge.

Further evidence for a generalized factor comes from regression analyses using total learning from each text as the dependent variable. Only the middle grade students were included in the regression analyses, since there were no standardized reading comprehension scores for the adult subjects. In predicting learning on each text, the strategy was to first take out the variance that is common to the two texts. Therefore, a stepwise regression was carried out with learning from the other text included first, with all of the other variables then entered stepwise. Overall, 75% of the total variance in history learning was accounted for by learning from the science text (48% of the variance), pre-test knowledge in history (an additional 17% of the variance), and standardized reading scores (an additional 9% of the variance). No other factors added significantly to predicting

history learning. The same procedure was carried out for predicting learning on the science text. Learning of the science text was predicted by learning on the history text (48% of the variance), and science pre-test knowledge, which accounted for an additional 7%.[8]

Measures of reading times provide further evidence for a generalized factor. The best predictor of reading time for one of the texts was reading time on the other text, r=.87. No additional variable added to the variance accounted for in reading time for either text.

The picture from these analyses is one of both generality and differences in learning across texts. If we look at history text learning, we can estimate that two factors reflecting general text learning abilities account for 57% of the step-wise variance (48% from science learning and 9% from standardized reading ability), with prior knowledge accounting for 17% of the variance. But there is an inequality in predicting text learning. Learning from the science text was not as well predicted, either by standardized reading scores nor by prior knowledge.

Evidence for Specific Text Factors. Total learning of the history and science was assessed separately for textrons--the basic concepts and their immediate propositions--and the connectors--the links among textrons. Let's consider textrons first. There was an

increase over grades in the recall of textrons (19% for 4th grade, 66% for college students). More interesting is the distinction between central and noncentral textrons. There were more central propositions recalled from the history text (48%) than non-central (20%), whereas for the science text subjects recalled about equal number of central (37%) and non-central propositions (35%). This difference was obtained for middle grade students only, however; college students recalled more central than noncentral information for both texts.

This difference may be partially explained by examining a breakdown in the word frequencies into those words that are specific to a text, such as "isthmus" and "electron", and those words that are general. Although the history text uses slightly less frequent words, the differences between the frequency of the text-specific and general vocabulary is greater for the science text. The mean word frequency for all text-specific vocabulary for history and science was 48 and 21 (per million) respectively, while the frequency of the general words were 456 and 876. Of course, both texts had lower frequency text-specific than general language. What is interesting is that, relative to the history text, the science text used many lower frequency text-specific words in higher frequency supporting text.[9] In other words, the science text was more dependent on the use of text-specific vocabulary, a

vocabulary that corresponds to non-central textrons. This would have been a greater problem for the middle grade students than for the college students, who have more experience with the text-specific vocabulary.

Consider now the text connectors, the referential and causal connections between textrons. There was a steady increase in the recall of connectors from 4th grade (16%) through colleges students (74%). More interesting is the difference between referential and causal connectors. Referential connectors, expressions of a concept's referential attributes, were generally recalled more often than causal connectors for the science text, in fact, dramatically so for middle grade students. Middle grade students recalled fewer than 10% of the causal connectors in the science text, whereas recall of referential connectors ranged from 18% for 4th graders to 31% for 5th graders. College students, by contrast, recalled 75% of referential connectors and 68% of causal connectors in the science text. This difference between referential and causal connectors was completely absent in the history texts at all grades. (Overall, 38% causal and 36% referential were recalled.) What all this amounts to is that there was a dramatic difference between the two texts, favoring history, in the recall of causal connectors.

The Role of Knowledge. The difference between the two texts

in the recall of causal connectors appears to implicate some role of specific knowledge. Using multiple regression procedures similar to those used for total learning, we asked what variables predicted the recall of connectors for the two texts. For the history text, the only significant predictor of causal connector recall was pretest knowledge in history, accounting for 35% of the variance (r=.59). Thus subjects who had more prior knowledge about Panama were the subjects who recalled more causal connectors from the text about the Panama Canal. For the science text, the only factor that predicted recall of the causal connectors was the standardized science test score, accounting for only 19% of the variance (r= .44). Students with the highest general science knowledge were the subjects recalling more connectors from the text on the atom.

A qualitative picture. We can illustrate some of these results by referring to the recall and interview protocols of the subjects. Most of the middle grade students were able to recall the more basic concepts in the history text--that there was a need for a canal, there were two problems in building it, and that it was finally built. By contrast, in response to the science text, students were not able to mention that an atom must be balanced, what "balanced" means, or how the balance changes when atoms are combined. In the history text, students were also able to connect things more. They made explicit connections between relevant parts

of the story, for example noting that workers got sick from disease and this caused a medical solution to the problem. In the science text, things were less connected. Clearly, learning from the science text was very superficial relative to the history text.

Summary. The results suggest that both general skills and domain specific knowledge help the reader learn from two very different subject matter texts. In support of a general factor is that the best predictor of learning from one text was learning from the other. In support of specific knowledge is the contribution that domain knowledge made to learning from both texts, especially to the history text. Also in support of specific knowledge is the fact that it predicted the recall of causal connectors in science.[10]

It is the text differences that may be most interesting however. For history, students produced coherent responses that included basic concepts and their simple propositions (textrons) and also referential connectors and causal connectors that linked them. For history also, all students were sensitive to the distinction between central and noncentral information. For history, specific prior knowledge predicted total learning, textron learning, and connector learning for both referential and causal connectors. For the science text, students produced less coherent responses, concepts with referential connectors but without causal connectors. For the science text, only college students were

sensitive to the distinction between central and noncentral text information. Finally, for the science text, prior knowledge was a less successful predictor for total learning but was the only factor that predicted the recall of causal connectors.

Conclusion

This section has reviewed research that supports the general principle embodied in a two-factor account of subject matter text learning. It is clear that both knowledge and general skill make contributions, and there is further evidence that they make different kinds of contributions. Knowledge is required for coherent representation of causal structures. General abilities serve comprehension, but perhaps without directly contributing to specific (causal) understanding.

What else is needed?

Our two factor account now has general reading comprehension abilities and specific knowledge in fairly complex relations. At one level of analysis, the two contribute in a trading relation--one source of knowledge can be traded for another. At another level of analysis, we see this is misleading: The two components contribute different things to the process of learning from text. Knowledge is especially needed to gain causal levels of understanding. General abilities seem especially to reflect superficial text understanding; and the most general abilities seem

to reflect reading processes that have their purest realization in reading speed, not comprehension.

The analysis raises questions, of course. For one, might not knowledge play a more pervasive role than merely causal understanding? For another, might not general ability play a more pervasive role than mere superficial understanding?

For both questions, the answer is "yes". Our conclusions are limited to the particular domains and texts that we studied. Specific knowledge will have a wider role, depending on a variety of factors, including the level of relevant knowledge. Certainly it is possible to create a text in which virtually no understanding is possible without knowledge. And general abilities will have extended roles, when knowledge demands are less or when the general abilities are taken to include a wider range of learning strategies, rather than a set of restricted reading abilities.[11] The general principle seems roughly correct, however: Generalized reading abilities are powerful in their range, superficial in the level of learning they allow; specific knowledge is limited in its range, deeper in the learning it allows. It is not that knowledge has to do with causal structures and reading ability has to do with words. It's rather that reading ability has to do with language processes, and knowledge has to do with non-language concepts.

Rather than try to make finer distinctions between general

ability and specific knowledge, however, we need to recognize the limits of the distinction when we deal with actual texts in practical ways. The distinctions are important theoretically, but they eventually run afoul of the practical facts of texts and learners, both of which mix non-language and language knowledge in confused blends. Things are less confused when we do the best analyses of texts and of learners that we can.

We leave the learners to someone else, but we conclude by returning to the analysis of texts that we discussed in an earlier section of this paper. The linguistic features of texts are more systematic and more important than has been acknowledged by superficial readability measures. The hostility toward these measures is understandable and, perhaps, regrettable to the extent that they have inhibited genuine linguistic analysis of text features. There are two areas in which closer analysis of texts can assist the task of understanding knowledge and general language abilities components in text learning. The first, which we will refer to as "subject matter genre", is the general form of the text's conceptual structure, and has elements of both form and content. The second, more strictly formal, is the specific syntactic features of the text.

Subject Matter Genre

For the first, consider again the Britt et al study, where we saw profound differences between our science and history texts, despite their superficial comparability. We also saw that these differences were partly in domain knowledge, not exclusively in text structure. History is a story, and its understanding depends, among other things, on temporal-causal structures. A history text takes advantage of the causal structure knowledge that people apply spontaneously to story understanding (Trabasso & van den Broek, 1985). A text about the atom does not ordinarily have this advantage, not just because atoms are not every day concepts, but also because they do not lend themselves to the temporal-causal structure.

This much may seem to be domain knowledge, but it gets necessarily reflected in text structure. A typical narrative is not a text structure arbitrarily imposed on an independent content, but a structure that naturally reflects the underlying content. To use a heuristically useful analogy to Gibsonian perception, one might say that the content of a story "affords" the structure of a narrative. The history of the American Civil War and the history of the Panama Canal naturally afford narrative discourse. It is not that one cannot make a story out of the atom, it is rather that the conceptual content of the physics of the atom, even at the level

aimed at middle grade learning, affords an expository text.

The text feature differences associated with these genres is quite dramatic. The narrative marks its temporal character with tensed verbs and lexical markers of time, such as "then", "later", etc. At the broader text level, its conventional paragraph sequencing recapitulates the temporal sequence of the events the text portrays. There are other important characteristics of narratives, of course, such as their development of personal goal striving and individual character. Another important characteristic of narratives is that children develop competence in narrative forms through oral language at an early age. Narratives thus provide a natural pre-schooling form to base text learning.[12]

By contrast, the expository form afforded by the physics of the atom is less familiar to students. We might suspect that it is not mere familiarity, but something more fundamental that produces learning obstacles for such texts. They lack the correspondence to every day life, which readily reveals some of the structure of the narrative. The expository text language corresponds to its nonnarrative conceptual content. It is typically tenseless, void of temporal markers, and its paragraphs flow, not by mimicking a sequence of events, but by connecting concepts through elaboration, extension, summarization, etc. It is possible to adapt expository content to narrative forms so that expository understanding might

benefit from transfer (Freedle & Hale, 1979). The general usefulness of, for example, writing stories about atoms, however, would seem to be limited by the basic structural differences between domains and by the realistic need to understand nonnarrative texts.

The most general point about subject matter genres is that they reflect both domain and nondomain components. A comparison of learning in two subject matters as different as physics and history will reflect mixtures of the two components. Research that will further address the separation of domain knowledge and text form must attend to separating them.

Syntactic Features of Text

There are characteristics that subject matter texts have by virtue of being written language, more or less independent of "genre". One we have already dealt with in an earlier section of the paper. Sentences must be parsed, and parsing is a quintessential language ability. It is fundamentally domain independent. As we argued, however, domain knowledge is not without an important role. The reader's knowledge provided important information concerning the repair of parsing errors, errors that might arise commonly even for skilled readers and more certainly for less skilled readers. The additional point to make here is simply that the syntactic structures of text are analyzable. It is

possible to develop thoughtful and linguistically insightful analyses of text syntax, not just with regard to parsing issues, but with anaphora, the process by which necessary antecedent information is inferred. It is surprising how little use has been made of such analyses, which can provide useful windows on the linguistic properties of texts in a way that keeps domain knowledge separable.

A second kind of syntactic text factor goes beyond the analysis of sentence constituents to the analysis of text signals. Givon (in press) demonstrates a variety of ways that syntax signals the reader about important semantically relevant information, including signals about topics and even about the importance of information in sentence predicates. Kintsch (in press) has made some intriguing use of Givon's analyses by showing how two of Givon's signaling functions can be used to predict readers' recall of texts. For example, Kintsch incorporated the signalling value of the indefinite "this". Experiments by Gernsbacher & Shroyer (1989) had shown the importance of such a signal, which is contrasted with the indefinite "a": Compare "I found this egg" with "I found an egg" as a fragment from a discourse. "This" signals more attention to the referent, the egg, than does "a". By adding activation to the referent in the reader's representation of the text, Kintsch was able to increase the power of his model (Kintsch,

1988) in predicting recall of text information. The details of how this comes about are important, because they have to do with how information is kept active in the reader's representation, which is a matter of local text coherence, and not some higher level text structure, such as independently determined causal connections. Kintsch (in press) found that not only does the addition of syntactic cues increase the power of his model to predict what gets remembered from text, it does as well as a model that specifically marks causal links.

The moral here is simple. Text researchers have ignored syntax for years, and they should not have. The syntactic structures of sentences contain signals to meaning. If the reader's goal is to construct a model of a situation (van Dijk & Kintsch, 1983), the text itself is an important guide to how to construct that model. Accordingly, when we separate features of domain information from features of text, we discover that there is quite a bit more to the latter than mere readability. And when we separate an individual's domain knowledge from his general language ability, we find there is quite a bit more to the latter than mere vocabulary size.

Summary and Conclusion

Contrasting two extreme approaches to subject matter text learning provides some insights into what is needed in a comprehensive account of text learning. Both specific knowledge and

general reading comprehension ability play large roles, but they are not exactly the same role. Our studies suggest that generalized abilities and specific knowledge can have a trading relation, but also that they have different contributions. General ability allows comprehension across different subject matters, whereas specific knowledge allows the construction of a deeper level of understanding within a subject matter. Texts themselves play a pivotal and complex role as the "interface" between specific knowledge and general comprehension ability. Much of what is ordinarily taken as an important general language factor, vocabulary, includes a large domain component. An essential general language process, parsing, also turns out to have a knowledge component, especially in parsing repairs. Thus one reason a history text may be easier to understand for some readers is that their ordinary knowledge helps them with syntactic problems. As a third complexity of text, the subject matter "genre" turns out to reflect a mix of underlying conceptual factors and the kinds of text forms that these underlying conceptual structures readily allow. Thus a history text may provide easier learning in part because it reflects the more familiar narrative structure that history itself, but not science, has intrinsically. Finally, although the role of text is complex, there are some clearly syntactic properties of text that play a large and underappreciated role in controlling the

reader's construction of meaning. The insightful analyses of texts holds promise for advancing understanding of how content (domain knowledge) and form (general ability) combine in text learning.

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Footnotes

1. Of course, the more carefully made argument is that the "vocabulary problem" has more than one source. One might claim that "everyday" vocabulary is not a matter of specific knowledge, but is general enough that it should be part of the general text-linguistic component. Furthermore, there are certain aspects of word meanings that are highly general and quite linguistic, in that they reflect generative semantic (and syntactic) properties. But we choose not to be subtle here, so we simply assume that most of what is ordinarily thought of as vocabulary is conceptual knowledge established through specific domain experiences. Note that, despite this assumption, the ability to learn vocabulary might be a generalized skill.

2. For one, example (1) contains a quantifier in the extended noun phrase--with more electrons than protons-- whereas (2) does not. Quantifiers can add to the processing load. Another difference is that in (1) the reader must establish two sets in interpreting the extended noun phrase. There is the set of atoms that have more electrons than protons and there is the set of atoms that do not have more electrons than protons. This amounts to an additional semantic complexity absent in (2), where there is no implied second set of negotiations.

3. It is important to establish that readers actually do make the kinds of syntactic misanalyses we are talking about here. And this is indeed what the evidence shows (Rayner, Carlson, & Frazier 1983). Furthermore, readers cannot always avoid the initial misanalysis by the use of context Ferreira and Clifton, 1986; Perfetti, 1990)

4. One confound in knowledge tests is domain interest. To the extent that general knowledge tests in a broad domain are predictive of learning, it is possible that the test results indicate a student's interest in learning more about the same general topic.

5. The earlier discussion of readability is relevant here. Is the presence of football-related words such as linebackers, blitz, down, etc. in the football story to count against the text's readability? Our claim is that they should not, but the readability

formula takes into account the proportion of words that is not on a list of high frequency words. Note in any case, whatever difference there is in the measured readability of these two texts favored the football story.

6. The design of the study created 4 groups of subjects. However, because there were age differences between the groups, the most straightforward description of results comes from ignoring the group boundaries and assigning every subject a score on the various measures and then using these measures as predictor variables in multiple regression.

7. We use these terms not to introduce new jargon regarding text units, but to reflect two aspects of our analysis: First, the analysis makes a distinction between text units that give basic unconnected propositions (textrons) and those that provide connections of various kinds (connectors). Second, although the units correspond to a certain extent the propositional units identified by Kintsch in his long term project on text (1974; in press; Kintsch & van Dijk, 1978), they do not correspond exactly.

8. This additional 7% was actually only marginally reliable statistically. We wish to be cautious in interpreting these regressions, because they are based on relatively small numbers of subjects. The overall predictability would have undoubtedly been higher had we included the college students or if the middle grade sample had been larger.

9. Although the lower frequency of science text-specific vocabulary is not surprising, the higher frequency of the general vocabulary from the science text might be more interesting. One possible explanation is that the syntax of the science text is highly simplified, and one gets a high proportion of high frequency articles and prepositions. We also note that trading off the general vocabulary against the specific vocabulary might be one way for a text to give a modest readability index.

10. Here it may be significant that our pretest of the knowledge about atoms was not as good a predictor as a standardized test of science knowledge. Our test tapped knowledge of relevant concepts, which might be less relevant to reconstructing causal explanations than whatever the standardized science test measures--a mix of general comprehension and knowledge, perhaps.

11. There are many discussions of such broader abilities or general learning strategies, including general text summarizing strategies (Palincsar & Brown, 1984), text elaboration processes (Bransford et al, 1982), and inference strategies (Paris, 1975). Segal, Chipman, and Glaser (1985) contains a number of other discussions of skills with general applicability. Such strategies are presumably quite important in extending basic text abilities. Acquiring them may be the best adaptation to the demands created by domain knowledge.

12. Extensive cross-disciplinary work on the comprehension of narratives has been carried out in the years since the early research of Stein & Glenn (1979) and Mandler & Johnson (1977). McCabe and Peterson (1991) contains a recent collection of papers on the development of narrative. The important contribution of most of this work to the present argument is their demonstration that narrative forms develop through oral language and are ar part of children's basic competence at an early age.